requires information on processor operation ranges and system buffer requirements that are a function of the system dynamics and control strategy. In general, the level of model complexity needed increases throughout the system design cycle. In the early design phase, simple dynamic models provide useful information for estimating the processing rates and storage sizes needed to meet all the system performance specifications. More complex models are needed for the design of control systems, the development of failure recovery approaches, and the plan for adding redundancy to the system in order to improve system safety and reliability.

A top-level dynamic system model of the ALSSITB has been developed at Ames Research Center (ARC) to investigate system design issues. The ALSSITB is currently being developed by Johnson Space Center (JSC) to support long-duration human testing of integrated life support systems. It comprises a set of interconnected test chambers with a sealed internal environment capable of supporting a four-person test crew for periods exceeding one year. The life support systems to be tested will consist of both biological and physical/chemical technologies that perform air revitalization, water recovery, biomass production, food processing, and solid waste processing. A variety of system designs for the ALSSITB have been studied to date.

Each system design is described in terms of the set of technologies used, the configuration of the technologies in the system, and the manner in which the system is operated. The overall technology set available for consideration includes technologies that provide various levels of regeneration. For example, life support consumables can be either supplied or produced, and waste products can be either processed, dumped, or stored. An optimal system generally consists of some combination of resupply, in situ resource utilization, venting, dumping, and material recycling using physical/chemical or biological processors. System configuration refers to the manner in which the processors are connected for a given set of technologies. For example, multiple flow paths are possible, as well as various options for the placement and sizing of buffers. System operation strategies need to be investigated because some system components can be operated in numerous ways. Some technologies can be operated in either batch mode or continuous mode. For batch operation, the batch sizes and operation schedule can vary. For continuous operation, processing rates can be either constant or variable, and the operational parameters, control objectives, and constraints can vary.

Among the ALSSITB designs simulated thus far are systems with different air revitalization systems using various circulation patterns, technology sets, and operational strategies. For each system design that was simulated, the results were compared with those of a baseline to see how well each system met performance criteria by maintaining controlled atmospheres, adequate reserves, etc., and to determine the required capacity for the various processors and storages.

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Activated Carbon from Inedible Biomass

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As manned missions become longer, resupply of life support materials becomes increasingly more difficult and expensive. The expense of resupply can be avoided by regenerating life support materials. Bioregeneration involves the use of plants to grow food, but plants generate a large amount of inedible biomass, which must be recycled. Incineration is one of the most promising technologies for recycling wastes such as inedible biomass. Unfortunately, inherent to the process of incineration is the formation of undesirable byproducts such as nitrogen oxides (NO_x) and sulfur oxides (SO_x). Conventional incineration technologies treat offgases, such as NO_x and SO_x, by using selective catalytic reduction processes, but these technologies require the injection of expendables such as ammonia to treat the NO_x. Activated carbon can also be used to remove NO_x and SO_x via the process of adsorption.

The Solid Waste Resource Recovery project group is investigating unique ways to use crop wastes to make activated carbon. This process would eliminate the need for expendables in the flue gas cleanup during long-duration, manned space missions. It may be possible to make this activated carbon from the inedible biomass available from growing plants in space. Over 40 crops are being considered for food production. One or more of these plants, which will provide the nutritional needs of crews on long missions, may be a good raw material for making activated carbon.

The flow diagram in figure 1 shows the planned role of the activated carbon as part of the incineration process for resource recovery. The contaminants in the flue gas are adsorbed on activated carbon at room temperature. In a regeneration process at high temperatures, the adsorbed NO_x is reduced by the carbon-forming nitrogen gas (N_2) and carbon dioxide. The offgases formed during the activation process are directed back into the incinerator. After several regenerations, the spent carbon is mixed with the incinerator feed and is converted to carbon dioxide and water in the incinerator. Thus contaminants are removed without the need for resupply.

The challenge is to make quality activated carbon, a highly porous, carbonaceous material. The porous structure is controlled by the nature of the starting material and the process used for carbonization and activation. Conversion of inedible biomass to activated carbon and the use of activated carbon to convert adsorbed NO_x to N_2 gas has been successfully demonstrated at Ames Research Center. There is an excellent chance that this research will result in a process that will one day be used to manufacture activated carbon in space for use in the life support system.

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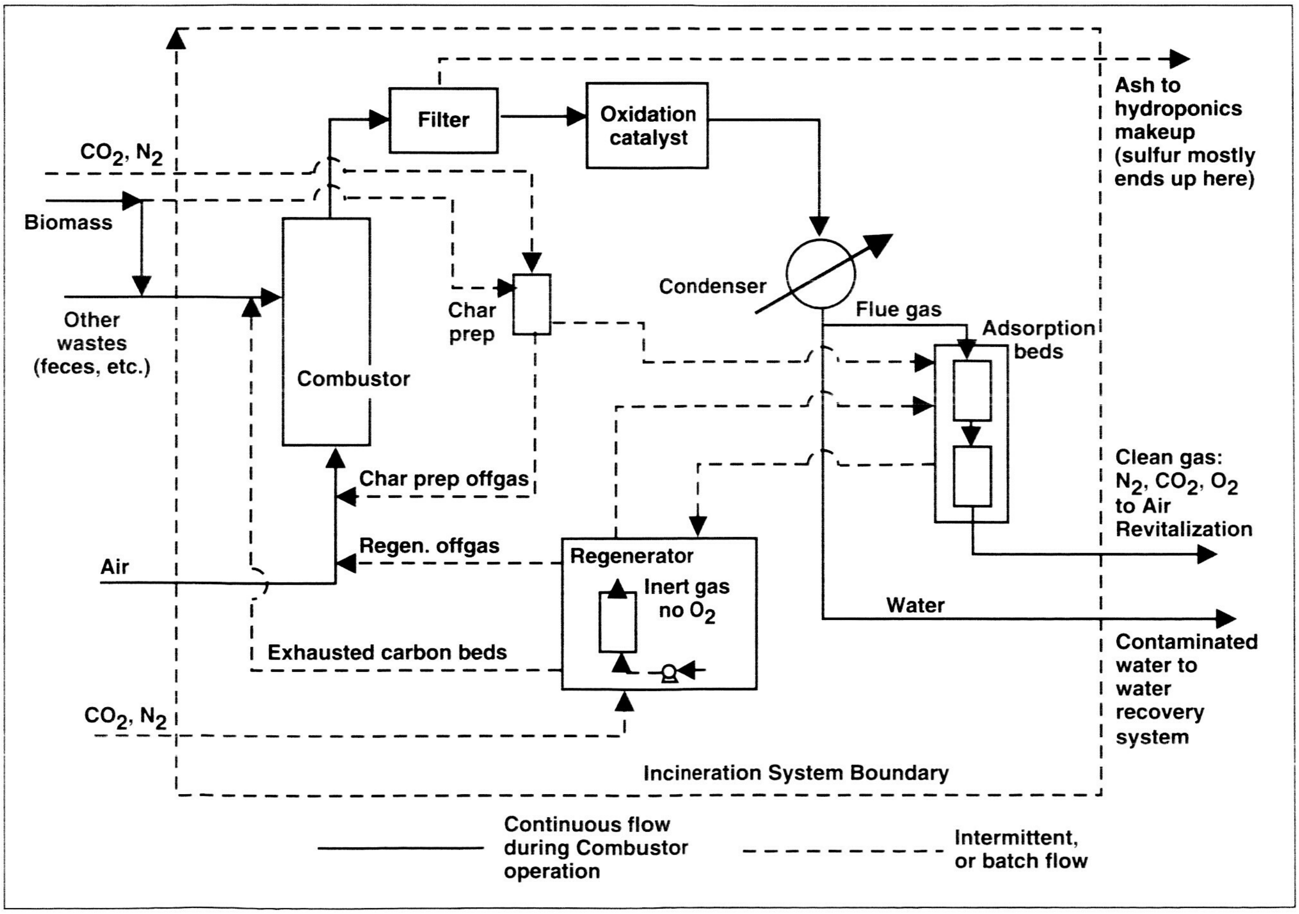

Fig. 1. Flow diagram of reactive carbon for flue gas cleanup.